

monise so closely with the twigs to which they cling that it is difficult to see where one begins and the other ends. Fig. 1 illustrates this insect in the attitude in which it was resting before being captured.

Another interesting insect from Ceylon is one of the moths, *Eurybrachis westwoodii*. The fore wings of this insect are marked in a mottled pattern of green, grey and brown, the hind wings being white, with deep claret-coloured marks near their base, and when it is on the wing the moth is an attractive-looking creature. But its appearance alters when it is at rest, with the mottled wings folded over the back. In Fig. 2 it is shown with the wings expanded as it appears when flying, and below is a piece of bark with the same insect resting upon it, where it was discovered by the keen sight of the collector—a clever capture, as will be admitted when it is noticed how excellently the wings and bark harmonise, and how they seem almost to merge one into the other.

There is found in Madagascar a small beetle which, looked at apart from its natural surroundings, has nothing specially interesting about it except that it is a conspicuous, rugged-looking, pure white and black insect, about three-quarters of an inch long. It feeds upon a species of fungus, which grows upon the bark of trees in mixed cream and black coloured patches. The beetle is shown at the

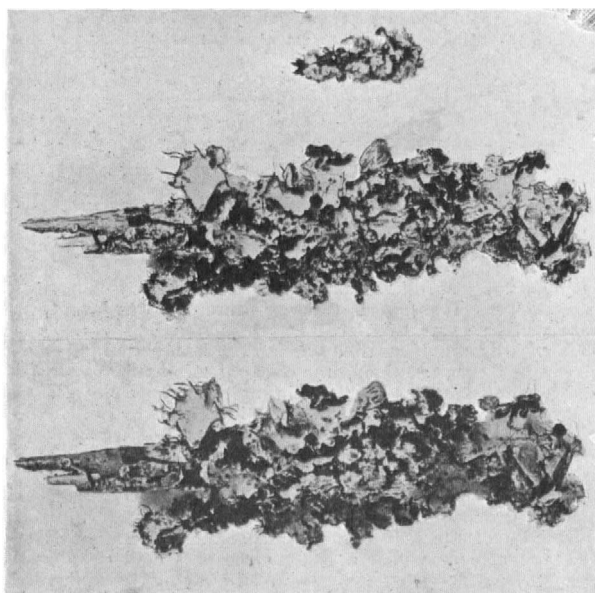


FIG. 3.—*Lithinus nigrocristatus* (Madagascar). The upper figures show beetle and bark separately, and in the lower figure the beetle is on the bark.

top of Fig. 3, and beneath it a piece of twig with the fungus growing upon it. At the bottom of the same illustration the same piece of fungus-covered twig is shown, but here the beetle is resting right in the middle of the fungus, effectually concealed amongst the vegetation upon which it feeds.

The paper is very fully illustrated by more than two hundred figures of the insects described, with the localities in which they were taken, covering the whole subject treated by Mr. Sykes.

Exception is taken to the use of the words "imago" and "imagine," introduced by Linnaeus, as representing the final stage of insect metamorphosis, and "matura" (maturus=to ripen) is suggested and employed as a substitute, conforming conveniently with the accepted terms for the earlier stages—larva and pupa. The word "mimicry" is also adversely criticised, as implying conscious resemblance, which is not known to exist, and "simulism," "simulation," "simulating," are substituted "as being at once expressive, explanatory and euphonious, and free from the inference of designed and cognitive resemblance."

REPORT OF THE CARNEGIE INSTITUTION, 1904.¹

IN NATURE for January 7, 1904, a list was given of the awards made by the Carnegie trustees for the prosecution of inquiries in various scientific directions. The third year book, just published by the board of trustees, contains reports upon most of these researches, but the time is far too short to gather in the full harvest, which may hereafter be expected, from so lavish and, presumably, judicious expenditure. There is abundant evidence that many well-known men, engaged in every department of science, have been enabled to attack problems which must otherwise have been neglected, or pursued with inadequate material and less energy. Beyond this general fact, the present volume does not, in most instances, enable us to estimate the results. The balance sheet attached shows that the trust is in a very flourishing condition, and that 267,000 dollars have been provided for inquiries, which the management discuss under the three heads of large, special, and minor grants.

Under the division of large grants, we have a description of the station erected, or adapted, for the study of experimental evolution at Cold Spring Harbour, some twelve miles from New York. Plans of the building are given, and a full account of the opening ceremony, at which Dr. Hugo de Vries gave a scientific address. The objects sought to be gained by such an institution are typical of the uses of the trust, and legitimately appeal to a liberal consideration. The investigations must be long continued, the results may be doubtful or negative, and it is a research which no individual or institution is likely to undertake on a scale sufficiently broad to produce decisive results.

Another far-reaching scheme, the Marine Biological Laboratory at Dry Tortugas, Florida, under the care of Dr. H. G. Mayer, is quite in its first stages of development, but one whose usefulness may be confidently predicted in due time. The buildings that have been erected consist of a main laboratory, 100 feet long, one story high, and with special arrangements for keeping the building cool in the hot weather of those latitudes. A feature in the construction of the laboratory and of the smaller buildings connected with it, is that all are made portable, so that they can easily be removed from their present site and erected elsewhere if thought desirable. Attached to the station is a sea-going vessel of light draft, fifty-seven feet over all, and sixteen feet beam, with a 20 h.p. naphtha engine. There is sufficient accommodation for seven men on board, and the vessel is specially designed to dredge in depths of 500 fathoms or less. Among other projects for which large grants have been made is the subject of economics, whose many subdivisions include, among others, population and immigration, mining and manufactures, banking and finance, social legislation and the labour movement, &c. Reports on all these subjects have been added, showing the scope of the respective inquiries and the progress that has been made. Historical research and terrestrial magnetism are the remaining two subjects which come under the division now being considered. On the latter subject we have some of the results of the discussion of the magnetic disturbance observed during the eruption of Mont Pelée, which are of special interest, since the inquiry discloses the fact that in certain respects the disturbance resembled those storms which are believed to be of cosmic origin.

The Transcaspien archaeological expedition and geophysical research are the subjects of special grants. The former is under the charge of Prof. Pumpelly, who left America in December, 1903, and began excavations in the following March, first attacking Anau, in Turkestan. By means of excavations in tumuli and by shafts sunk in the city of Anau, the exploring party has traversed some 170 feet of the accumulations of successive generations of peoples, extending from recent times, through the iron and bronze civilisations, and some 45 feet deep into the stone age. Among the objects of this investigation is the hope of throwing some light on the source of our domestic animals.

The reports on the subjects of the so-called smaller grants cannot be particularly referred to here. The inquiries cover

¹ Carnegie Institution of Washington. Year Book, No. 3, 1904. (Washington: Published by the Institution, 1905.)

the whole ground of physical science, and are in many instances of the greatest importance, but generally have reference to definite researches undertaken by individuals not calling for wide cooperation. A list of papers, prepared possibly to pave the way for future applications, is added, in which are discussed the conditions of solar research at Mount Wilson, by Prof. Hale; the southern observatory project, by Prof. Boss; fundamental problems of geology, by T. C. Chamberlin; plans for obtaining subterranean temperatures, by G. K. Gilbert; magnetic survey of the Pacific Ocean, by L. A. Bauer; and geological research in Eastern Asia, by B. Willis.

THE RECEPTION AND UTILISATION OF ENERGY BY A GREEN LEAF.

THE subject of my lecture is derived from the series of papers laid before the society to-day by my colleagues and myself, dealing with some of the physiological processes of green leaves. In giving an account of some of these investigations I shall dwell mainly on their relation to the *energetics* of the leaf, and shall endeavour to show how the leaf behaves under various conditions when regarded from the point of view of the exchange of energy between itself and its surroundings.

One of the problems which we attempted to solve was to draw up a "revenue and expenditure account" of energy for a green leaf, showing the proportion of the incident energy absorbed, the amount of this absorbed energy which is used up for the internal work of the leaf, and the proportion which is dissipated by re-radiation and the losses due to the convective and conductive properties of the surrounding air under varying wind-velocities.

Of these various factors, the one I have last mentioned, which presupposes a knowledge of the *thermal emissivity* of the leaf-surface, presented by far the greatest difficulty; but during the past year Dr. W. E. Wilson and I have been able to devise a suitable method for determining the thermal emissivity of a leaf-surface in absolute units, so that our story is now fairly complete.

The discussion of the thermal relations of a leaf to its surroundings will be simplified if we first consider the case of a leaf when it is shielded from solar radiation. We will assume that a detached leaf, freely supplied with water, is placed in an enclosure the walls of which are non-reflective and are maintained, along with the enclosed air, at a perfectly uniform temperature t . We will further assume that the air is saturated with water-vapour.

Under these conditions the system would remain in thermal equilibrium if it were not for the respiratory processes going on within the leaf-cells. These are exothermic in their final result, so that the state of complete thermal equilibrium can only be attained when the temperature of the leaf has risen to a point t' , somewhat higher than t . The magnitude of the difference $t' - t$, representing the maximal thermometric disturbance between the leaf and its surroundings, will depend on three main factors:—

- (1) On the rate of evolution of the heat of respiration.
- (2) On the rate at which this heat is dissipated by the thermal emissivity of the leaf-surface, and,
- (3) On the magnitude of the slight rise of partial pressure of the water-vapour in the interspaces of the leaf, which gives rise to a certain amount of diffusion of water-vapour through the stomata.

The rate of evolution of the heat of respiration can be deduced with sufficient exactness from the amount of carbon dioxide liberated per unit area of the leaf-lamina in unit of time, since there is evidence that the carbon dioxide proceeds from the oxidation of a carbohydrate with a heat of combustion which cannot be far removed from 3760 calories per gram. Taking the concrete example of a leaf of the sunflower respiring at the rate of 0.70 c.c. of carbon dioxide per square decimetre per hour, it can be shown that the heat of respiration in this case amounts to about 0.00582 calorie per square centimetre of leaf-lamina per minute. From the known weight of a square centimetre of the leaf-lamina, and its specific heat, this

spontaneous liberation of energy within the leaf might conceivably raise its temperature through 0.033°C . per minute, provided there were no simultaneous losses due to radiation, conduction and convection of the surrounding air, and internal vaporisation of water. All these sources of loss, of course, become operative immediately the temperature of the leaf exceeds that of its surroundings. We shall see presently that the thermal emissivity of this leaf in still air is 0.015 calorie per square centimetre of leaf-surface per minute, for a difference of temperature of 1°C . between the leaf and its surroundings, so that the temperature of the leaf, under the conditions postulated, cannot exceed that of its surroundings by more than

$$0.00582/2 \times 0.015 = 0.019^\circ \text{C}.$$

But this is assuming that transpiration has been in abeyance, which is certainly not the case, so that this small temperature difference of 0.019°C . will be still further reduced.

The main point which I wish to bring out here is that the thermometric disturbances due to the processes of respiration are very small, so small, in fact, that they may be neglected in considering the large disturbances induced by other causes.

Let us now suppose our leaf to be placed under the same conditions as before, but in air which is not fully saturated with aqueous vapour for the temperature t .

The conditions are manifestly unstable owing to the excess of the partial pressure of the water-vapour in the saturated air of the interspaces of the leaf over that of the vapour in the unsaturated air outside.

The diffusion-potential thus set up will result in water-vapour passing outwards through the stomata, and the temperature of the leaf will fall. This fall will continue until the gradient of temperature between the surroundings and the leaf is sufficiently steep to allow energy to flow into the leaf from without at a rate just sufficient to produce the work of vaporisation, at which point a steady thermal state will be established which will remain constant so long as other conditions are unaltered. The leaf will then have assumed a temperature t' , which in this case will be lower than that of its surroundings.

Now it is manifest that when this steady thermal condition has been attained, the amount of water vaporised per unit of area of the leaf in unit of time must be a measure of the energy flowing into the leaf for the gradient of temperature represented by $t - t'$, and provided we determine the amount of water lost by the leaf, and the temperature difference between the leaf and its surroundings under the steady conditions, we have all the data necessary for finding the *coefficient of thermal emissivity* of the leaf-surface in absolute units, that is to say, the rate at which a leaf-surface will emit or absorb energy from its surroundings in still air for a difference of temperature of 1°C .

Following out this idea, Dr. Wilson and I have successfully determined the constants of thermal emissivity for leaves of different kinds, both under "still-air" conditions and in air-currents of determinate velocity. The results are interesting from several points of view, since amongst other things they enable us to estimate the rate at which the excess of solar radiant energy falling on a leaf is dissipated by mere contact with the air moving at any ordinary wind-velocity, and they also give us, under certain conditions, a means of deducing the actual rate of transpiration from mere observations of temperature-differences.

Before proceeding to show more in detail the manner in which the thermal emissivity of a leaf is determined, we will turn for a moment to the magnitude of the difference of temperature between a leaf and its surroundings which may be expected from a given rate of transpiration. We will assume that the leaf of a sunflower, transpiring into the unsaturated air of the enclosure, when the steady thermal condition is attained, is losing water at the rate of 0.5 gram per square decimetre per hour, or 0.000833 gram per square centimetre per minute.

The heat required to vaporise this amount of water at 20°C . is $0.000833 \times 592.6 = 0.4938$ calorie, which, on the theory of exchanges, must represent the amount of energy entering and leaving a square centimetre of the leaf-lamina per minute. The thermal emissivity of this leaf

¹ The Bakerian lecture, delivered at the Royal Society, March 23, by Dr. Horace T. Brown, F.R.S.